§ 6. Particle Transports and Related Fluctuations on LHD

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Dependence of the particle confinement coefficients on the electron temperature under constant electron density (line averaged density is around $1.4\times10^{19}m^{-3}$) are estimated from the density modulation experiments at Rax (magnetic axis position)=3.6m and Bt=2.8T on LHD[1]. The scan of the temperature was done by the change of the power of NBI from 0.98 up to 6.9MW. Density was sinusoidally modulated by the modulated gas fuelling. The amplitude of the density modulation was kept less than 2.5% of the line density along the central chord. The modulation frequency was 2 and 5 Hz, which was determined to have about 5 ~ 10 periods during a density flattop. Particle diffusion coefficients (D_{exp}) and convection velocity were obtained from the propagation of the modulated density. To simplify the analysis, spatially constant D and V(r)=r/a V are used for the analysis.

Fig.1 (a) and (b) shows temperature dependence of D and V respectively. In Fig.1 (a), effective thermal diffusion coefficients χ_{eff} from power balance analysis and neoclassical particle diffusion coefficients D_{neo} with DCOM code are also shown. Although spatially constant D are used for the analysis, the peak of the modulation is located around ρ=0.75,so obtained D_{exp} from modulation experiments are weighted around ρ =0.75. Therefore, Te at ρ=0.75 are used for the estimation of the temperature dependence and χ_{eff} and D_{neo} at ρ =0.75 used for the comparison. χ_{eff} is 3 ~ 5 times larger than D_{exp}. The particles are better confined than energy. T_e is dominant parameter to determine D_{exp} under constant density in this experiment regime (plateau regime) and D_{exp} is proportional to $Te^{1.38}$. D_{exp} is more than one order larger than D_{neo}. The particle diffusion is anomalous in this experimental regime. However, the difference between D_{exp} and D_{neo} becomes slightly smaller at higher T_e. On the other hands, V indicates small inward pinch (0~-2m/sec) and shows weak temperature dependence as shown in Fig.1 (b).

Microturbulence is observed by Phase Contrast Interferometer (PCI) in two different confinement discharges within $0.1 < k_{poloidal} < 1.25\ mm^{-1}$ and $5 < f < 125$ kHz ranges[2]. By using magnetic shear, local measurement around the minor radius was possible. One discharge is 1-MW and the other is 6.5-MW NBI heating both with Rax = 3.6 m, the global energy confinement time is 264 and 94 ms respectively. The difference of the temperature from the available central ion temperature, is factor 1.5. From the results of the modulation experiments, the difference of D_{exp} is expected in factor $1.5^{1.38} = 1.7$. From Fig. 1 (a) and (b), factor 1.5 in temperature difference results in modification of D rather than V. As shown in Fig. 2, the edge density is almost the same, however, a clear difference of the spectrum of the fluctuation was observed as shown in Fig.2 (b) and (c). For simple random motion diffusion process, if the diffusion process is determined by turbulence, the diffusion coefficient is given as follows,

$$D_{random} \propto \frac{(Correlation \quad length)^2}{Correlation \quad time} = \frac{\delta f}{k^2}$$

Here, δf is the frequency width and k is the perpendicular wave number of turbulence. For worse confinement (6.5-MW heating), the width of frequency spectrum is around 2.4 times wider than that of the better confinement (1-MW heating), and the peak wave number is 2/3 of the case with 1-MW heating as seen in Fig.2 (b) and (c), respectively. This results in,

$$\frac{D_{6.5MWheating}}{D_{1MWheating}} \approx 2.4x(3/2)^2 = 5.4$$

This does not agree expected factor 1.7 difference of D. The uncertainty of frequency width can affect. However, rough correlation between increase of D and change of fluctuation spectrum is observed.

References

1)Tanaka, K., et al., EPS2003 Proceedings
2) Sanin, A., et al., EPS2003 Proceedings

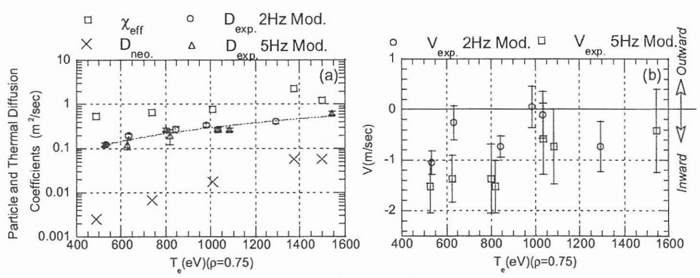

Fig.1 Temperature dependece of (a) D and (b) V under constant density

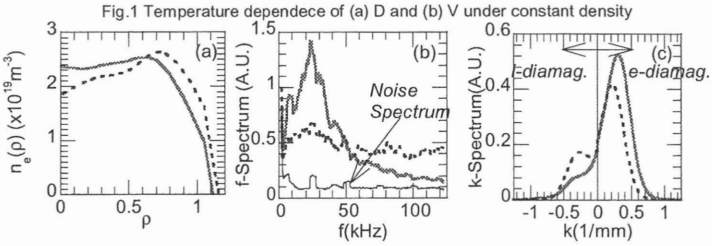

Fig.2 (a) Denisty proifles (b) Freqeuncy and (c) wavnumber spectrum measured by PCI. Plain lines indicate PNBI=1MW,τ_e=260ms,Ti(0)=1.3keV, Dash lines indicate PNBI=6.5MW, τ_e=94ms,Ti(0)=1.9keV.